

**A method for dew point measurement and a device for carrying out said method****Field of the invention**

The invention relates to a field of measuring engineering, and in particular, to a measurement of humidity of gases by a technique of a dew point, and may be used in dew - point hygrometers, indicators of a corroding condensate, as well as in aims of research for determination of a concentration value of condensed admixtures in a predetermined volume of gas to be studied and a temperature of hydrate formation in a gas etc.

**Prior Art**

It is known a method for dew point measurement comprising feeding gas to be studied onto a cooled portion of an optically transparent body through which is directed a light flux, and registering a change of a light flux intensity, advent of the dew point being determined on the basis of the registered change, as well as a device for dew point measurement implemented in a given method, the device comprising the cooled portion of the optically transparent body, the portion is included in a housing and connected through light guides with radiators and a light flux transducer being connected to a register, the device comprising also a cooler and a temperature sensor (see SU patent №1744618, Int. Cl. G01N 25/66, published June 30,1992).

The drawback of the known technical solutions is a low reliability because of possible pollutions with admixtures of gas to be studied of the optically transparent body because of which arise a unnecessary layer which may bring to inaccurate measurements and a loss of efficiency in operation.

The method to be closest to the proposed one by a technical essence is a method for dew point measurement, comprising feeding gas to be studied onto a cooled element with a condensation surface onto which a light flux is directed and registering the value of the light flux reflected from the condensation surface, advent of the dew point being determined on the

basis of the registered value (see the RF patent №2085925, Int. Cl. G01N 25/08, published July 20, 1995).

The drawback of the known method is a relatively low accuracy of measurement caused by a presence of a relatively long transient process when measuring.

The device to be closest to the proposed one by a technical essence is a device for dew point measurement, comprising a cooled element contained in a housing equipped with a sampling tube, the cooled element is provided with a condensation surface and is connected through an optical element to a radiator, the proposed device comprises further a register, a cooler and a temperature sensor (see the RF patent №2085925, Int. Cl. G01N 25/08, published July 20, 1995).

The drawback of the known device is a relatively low sensitivity which decreases the accuracy of measurement since the transient process when fixing the dew point is relatively long.

Functionalities of the known device are limited, moreover, only by its basic purpose - by the measurement of the dew point.

### **Disclosure of the invention**

In base of the invention is stated a task of increasing the accuracy of measurement owing to increasing the sensitivity.

An additional technical task is widening of functionalities owing to providing a measurement of a concentration value of condensed admixtures in a predetermined volume of the studied gas during a certain period of time, as well as owing to a reliable registration of water drops or hydrates and a possibility of autocalibration.

This task is solved by the fact that in a method for dew point measurement, comprising feeding gas to be studied onto a cooled element with a condensation surface onto which a light flux is directed and registering the value of the light flux reflected from the condensation

surface, advent of the dew point being determined on the basis of the registered value, a light flux polarized in a plane of its incidence is used, and the angle at which it is directed onto the condensation surface of the cooled element is selected so that there is no reflection of the light flux in the absence of a condensate from the condensation surface of the cooled element, which is made of a dielectric, besides, a phase difference between beams reflected from the condensation surface of the cooled element and from the surface of a condensate film is additionally measured, thickness  $h$  of the condensate film on the condensation surface of the cooled element is determined, and the concentration of condensed admixtures in a predetermined volume of the studied gas is determined on the basis of the value of the thickness of the film formed during a certain period of time.

In accordance with another invention, in a device for dew point measurement comprising a cooled element contained in a housing equipped with a sampling tube, the cooled element is provided with a condensation surface and is connected through an optical element to a radiator, a register, a cooler a temperature sensor, the cooled element provided with a condensation surface is made in the form of a dielectric plate, the radiator - in the form of a source of light polarized in the plane of incidence thereof, wherein the optical element is positioned in such a manner that the light flux of the source of polarized light is directed onto the condensation surface of the cooled element, preferably at an angle, the tangent of which is equal to the refraction index - Bruster angle, herewith the direction of the polarized light flux onto the condensation surface of the cooled element is selected at an angle within the range of  $\pm 9^\circ$  of the value of the Bruster angle, besides, the device is provided with at least one additional register serving for measurement of scattered beams reflected from the surface of the formed condensate, wherein the housing is equipped with a cooler and a temperature sensor which are mounted on the sampling tube thereof.

The essence of the invention is that a usage of the light flux being polarized in the plane of its incidence and directed at Bruster angle onto the dielectric surface of the cooled element allows to provide a substantial increase of the sensitivity to an appearance of condensed admixtures that increases the accuracy of the dew point measurement. Besides, appear additional opportunities to study the gas, to autocalibrate the device that widens functionalities of the device.

### **Brief description of the drawings**

Fig. 1 illustrates a structure of the claimed device, Fig. 2 shows a diagram elucidating a principle of measurement of an increment of thickness of the deposited film.

### **Best variant of an embodiment of the invention**

A method for dew point measurement is in feeding gas to be studied onto a cooled element with a condensation surface onto which a light flux is directed and in registering the value of the light flux reflected from the condensation surface, advent of the dew point being determined on the basis of the registered value.

A peculiarity of the invention is that a light flux polarized in a plane of its incidence is used and it is directed onto the condensation surface of the cooled element at an angle at which one is no reflection of the light flux from the condensation surface of the cooled element which is made of a dielectric.

It should be noted that in accordance with Bruster law if the light flux falls onto the surface of a dielectric at the angle  $\alpha$  the tangent of which is equal to the refraction index then the light reflected from the surface of the dielectric is fully polarized (see [www.RUBRICON.ru](http://www.RUBRICON.ru), Russian Encyclopaedia).

Therefore when falling the light, being polarized parallel to a plane of incidence (p - component), onto a dielectric surface in the absence of a condensate no reflection takes place from the polarized beams being fed onto this surface since they are refracted into a reflecting

medium i.e. are absorbed in a dielectric (see Appendix: B.S.E.(Big Soviet Encyclopaedia), Mirror reflection of light, ). And when appearing a condensate a part of light polarized flux does not reach a dielectric, and instantly takes place a reflection of the polarized beams and a reflected light flux is fixed by register.

For determining a value of concentration of the condensed admixtures in a predetermined volume of the studied gas the phase difference between beams reflected from the condensation surface of the cooled element and from the surface of a condensate film is measured, and thickness  $h$  of the condensate film, for example, of heavy hydrocarbons or spirit on the condensation surface of the cooled element is calculated in accordance with the formula:

$$h = \frac{(\varphi - \pi) \cdot \lambda}{2\pi \cdot 2 \cdot n_1 \cdot \sin \alpha \left( \frac{1}{\sin \beta \cdot \cos \beta} - \operatorname{tg} \beta \right)},$$

where  $\varphi$  - the phase difference between beams,

$\lambda$  - the wavelength in vacuum,

$n_1$  - the refraction index of gas to be studied,

$\alpha$  - Bruster angle,

$\beta$  - the angle of the refraction of a beam in the condensate film.

After that on the basis of the thickness of the film being formed during a certain period of time the concentration of the condensed admixtures is determined.

The device for dew point measurement which realizes the claimed method comprises a housing 1 equipped with sampling tube 2, the housing 1 contains a cooled element 3 provided with a condensation surface and connected through an optical element 4 to a radiator 5. Besides, the device further contains a register 6, a cooler 7 and a temperature sensor 8.

A peculiarity of the invention is that the cooled element 3 provided with the condensation surface is made in the form of a dielectric plate, the radiator 5 - in the form of a source of light polarized in the plane of incidence thereof.

Herewith the optical element 4 is positioned in such a manner that the light flux of the source of polarized light is directed onto the condensation surface of the cooled element 3, preferably at an angle, the tangent of which is equal to the refraction index (see the Bruster angle, Russian Encyclopaedia).

The selection of this angle is made within the range  $\pm 9^\circ$  of the value of Bruster angle.

The indicated range is selected on the basis of experimental tests.

Besides, the device is provided with at least one additional register 9-1 serving for registration of water, as well as with a second additional register 9-2 serving for registration of ice which are formed on the condensation surface of the cooled element 3.

It should be noted that the housing 1 is equipped with a cooler 10 and a temperature sensor 11.

A positioning of registers 9-1 and 9-2 is selected experimentally. The sampling tube 2 has a bottom 12, inlet and outlet holes 13 and 14 accordingly. This provides a fixation of a predetermined volume of the studied gas.

An optical element 4 through which passes a light flux 15 is hermetically sealed with help of a packing ring 16.

#### **The device operates in the following manner.**

When positioning the device into the medium of the gas to be studied or an admixture of gases the last goes onto the condensate surface of the cooled element 3, and in case of absence in it of condensate admixtures the condensate is not deposited and the polarized light flux being directed at Bruster angle is not reflected from the surface of the dielectric since it is absorbed in it.

The register 6 does not fix the light beams therefore and does not take place a registration of the dew point temperature.

In the presence of condensed admixtures in the gas to be studied on the condensation surface of the cooled element 3 at a definite temperature are formed a layer of the condensate and/or small dispersion drops of ball - shaped form or crystals of hoar-frost or hydrates.

Owing to the reflection of the light flux from the surface of condensate at a definite temperature of the cooled element 3 takes place an operation of the register 6.

It should be noted herewith that the registration of the light flux takes place even at an insignificant appearance of the condensate on the condensation surface of the cooled element 3. This defines the high sensitivity of the device and therefore the accuracy of the measurement.

The proposed device allows to determine the value of the concentration of condensed admixtures in a predetermined volume of the studied gas owing to the measurement of the increment of a thickness of the deposited film (see Fig. 2).

In this case a reference number 17-1 nominates gas to be studied which has the refraction index  $n_1$ , 17-2 nominates a deposited film having the thickness  $h$  and the refraction index  $n_2$ , and a 3 - the cooled element made of dielectric having the refraction index  $n_3$ .

This structure is illuminated with the light source being polarized parallel to the plane of its incidence at the angle  $\alpha$  - Bruster angle. On two interfaces take place reflections.

An analysis shows that when

$$\alpha = \text{arctg} (n_3/n_1) \quad (1)$$

the coefficients of reflection from both interfaces are equal in magnitude and are opposite in phase.

The phase difference  $\varphi$  between beams passing to the register along the trajectories OAB and OC is determined in accordance to the following expression:

$$\varphi = \frac{2\pi}{\lambda} \cdot 2 \cdot h \cdot n_1 \cdot \sin \alpha \cdot \left( \frac{1}{\sin \beta \cdot \cos \beta} - \operatorname{tg} \beta \right) + \pi, \quad (2)$$

where  $\lambda$  - the wavelength in vacuum.

It is clear that the phase difference  $\varphi$  - the periodic function of thickness  $h$  of the film, therefore when the interference of beams reflected from to interfaces takes place the intensity of the light coming to a photodetector of light will be also the periodic function of  $h$ . By means of calculation of periods of changing the intensity of the light is determined the increment of thickness of the film -  $h$ .

The condition (1) corresponds to Bruster angle for the interface "gas-substrate" i.e. for the thickness of the film being equal to zero. At small deviations from the condition (1) the described effect does not disappear in the range  $\pm 9^\circ$ , however the amplitude of modulation of the intensity of the light is decreased due to a violation of equality of coefficients of reflection.

After that may be determined the thickness  $h$  of the condensate film in a accordance with the formula:

$$h = \frac{(\varphi - \pi) \cdot \lambda}{2\pi \cdot 2 \cdot n_1 \cdot \sin \alpha \left( \frac{1}{\sin \beta \cdot \cos \beta} - \operatorname{tg} \beta \right)}, \quad (3)$$

where  $\varphi$  - the phase difference between beams,

$\lambda$  - the wavelength in vacuum,

$n_1$  - the refraction index of gas to be studied,

$\alpha$  - Bruster angle,

$\beta$  - the angle of the refraction of a beam in the condensate film.

After some conversions may be obtained the following:

$$h = (\varphi - \pi) \frac{\lambda \cdot \operatorname{tg} \beta}{4\pi \cdot n_1 \cdot \sin \alpha}. \quad (4)$$



When using the refraction law may be obtained the most convenient formula for the calculation of the thickness  $h$  of the film:

$$h = (\varphi - \pi) \frac{\lambda \cdot \operatorname{tg} \left( \operatorname{ArcSin} \left( \frac{n_1 \cdot \sin \alpha}{n_2} \right) \right)}{4\pi \cdot n_1 \cdot \sin \alpha}, \quad (5)$$

The additional registers 9-1 and 9-2 are used for fixing the appearance of small dispersion drops of ball-shaped form and crystals of hoar-frost or hydrates accordingly. Herewith their positioning is determined by experiment.

The cooler 10 and the temperature sensor 11 are used for preliminary cooling of the gas positioned in the sampling tube 2. Herewith the dew point temperature in the volume of the tube 2 becomes equal to the temperature of the tube 2. Therefore the dew point temperature at the meter indirectly corresponds to the same temperature that may be used when autocalibrating the device.

The shape of the optical element 4 may be different one. The chief main think is the direction of the light flux 15.

Thus, in the proposed technical solutions is achieved the stated technical result - increasing the accuracy of measurement at the widening of functionalities.

### **Industrial applicability**

The described advantages of the proposed technical solutions ensure them the possibility of wide industrial usage in the field of the measuring engineering for the measurement of humidity of gases by a method for dew point measurement and may be used in dew-point hygrometers, indicators of corroding condensate, as well as in aims of research for determination of a concentration value of condensed admixtures in a predetermined volume of a gas to be studied and a temperature of a hydrate formation in a gas etc.